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Experiments with arsenites

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*EXPERIMENTS WITH ARSENITES.

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Paris green was brought into prominence as an insecticide for the first time in this country in 1869 and London purple in 1877. Arsenious acid (white arsenic) was successfully used for the destruction of the Canker-worm as early as 1875 and is still frequently recommended for the destruction of insects. During these years the arsenites have arisen to the first rank as insect destroyers. They have been largely experimented with by entomologists and widely used by farmers and fruit-growers, and yet there is much difference of opinion as to the proportions in which each may be safely applied to different plants for the destruction of insects. In fact a serious obstacle in the way of a more free and successful use of the arsenites has been their liability to injure tender foliage, even when applied very dilute. In the experiments of the past two seasons, herein reported, I have given much attention to the finding of some method of applying these poisons so as to prevent injury to foliage without lessening their effectiveness in destroying insect life, and the success met with in this direction has been most gratifying. I also give the results of experiments to determine relative injuries to foliage from applications of the arsenites when freshly mixed and when allowed to stand a few days before being applied; to show the effect upon foliage by adding paste or soap to arsenical mixtures; to show the effects of sun, dew and rain upon foliage treated with arsenical mixtures; to show whether or not it is practical and safe, so far as injury to the plant is concerned, to mix the arsenites with insecticides that kill by external contact; and to show the effects of combining the arsenites with fungicides.

I need not take time to dwell upon the importance of these investigations, which must be apparent to all, but will proceed at once to a consideration of the experiments themselves.

*This paper, except certain changes and additions, was read before the Society for the Promotion of Agricultural Science, at Indianapolis, 1890.

Mode of Application.

In arriving at the results given in this paper more than a thousand applications have been made and their effects carefully watched and noted for weeks afterward. As a large proportion of the applications were necessarily made in proportions that would seriously injure foliage, in order to get comparative effects, it is evident that it would not do to treat entire trees of the valuable varieties that had to be used; so the applications were made in most cases to a few carefully selected twigs, bearing perfect foliage, where every leaf could be thoroughly treated. Most of the applications have been made with a bellows-sprayer or atomizer, made by Thomas Woodason, Philadelphia, Pa.

A great many of the applications, especially those made in 1889, are inconvenient for tabulation, and do not appear in the tables. A partial report upon these experiments was made at the meeting of Economic Entomologists at Washington, in November last. The doubtful conclusions there given have, in every case, been verified by subsequent experiments.

Sources of Error.

Glaring exceptions occasionally occurred in these experiments and a few words are necessary in regard to the sources of error as I found them in the course of my work.

Condition of the Foliage.—The oldest leaves are most susceptible to injury. They often turn yellow and drop while younger ones become spotted with brown and do not fall, unless the injury is severe. If the tree is not examined until the old leaves have dropped, which is usually the first indications of injury, it may be thought that little or no harm has been done, when really the tree has lost ten or fifteen per cent of its foliage.

Applications to leaves attacked by a fungus will often appear to do serious harm, while leaves not bearing the fungus will remain uninjured. In several instances I have had to discard my results on this account.

Position of the Leaves.—The position and shape of the leaves often have much to do in determining the amount of poison that may be retained upon their surfaces, and hence the amount of injury that they will receive.

Effects of Rain, Dew and Sunlight.—Heavy dews and direct sunlight, and, perhaps, very light rains, increase the

damage that the arsenites produce upon foliage, while a heavy rain or a dashing shower will materially lessen the injury by removing the poison from the leaves, especially of the most exposed parts. It is therefore necessary that applications for comparison should be made the same day and upon foliage equally exposed to rain, dew and sunlight, or results that are misleading and contradictory are almost sure to follow.

In support of the above statements I give the following experiment:

Two large Chrysanthemum plants were chosen and a number of leaves upon each were dusted freely with pure London purple, Paris green and white arsenic, respectively. One half of the treated leaves in each case were daily moistened with pure water from an atomizer, while the others were carefully kept dry. One plant was kept in a south window and the other was kept out of the direct rays of the sun. The following note was taken at the end of two weeks: "None of the leaves that have been kept dry have been injured. Of those that were wet each morning, London purple has destroyed all, whether in direct sunlight or not. White arsenic did fifty per cent damage to the moistened leaves in direct sunlight and slight injury to those in the shade. Paris green did fifty per cent injury to to moistened leaves in direct sunlight and no injury in the shade."

From the above experiment and repeated observations I feel quite safe in saying that foliage most exposed to dew and direct sunlight will be most injured by the arsenites, other things being equal. Leaves kept perfectly dry can hardly be injured by the arsenites.

Other Sources of Error.—Other sources of error, such as a misplaced label or note, or a failure to have the mixture thoroughly stirred before applying, etc., are liable to occur occasionally, and when once made cannot be detected.

Estimation of Injuries.

The injuries put down in the following tables are all estimated and the amounts expressed in decimals. When .01 is given it means the slightest noticeable spotting of the leaves; .02, a little worse than .01; .05, about one twentieth of the leaf surface destroyed; .50, one half of the foliage destroyed, etc.

TABLE I.

Table Showing Comparative Injuries to Foliage from London Purple, Paris Green and White Arsenic, when freshly mixed and applied in Water.

		1 Pound to 25 Gallons.	1 Pound to 50 Gallons.	1 Pound to 100 Gallons.	1 Pound to 200 Gallons.	Applied.	Noted.	Days standing.
London Purple		.05	0	.02	0	May 21	June 11	21
		.20	.05	.10	.....	May 29	June 18	20
		.85	.75	.80	.08	June 6	June 18	12
	Plum	.80	.70	.30	.....	June 16	July 1	15
		.75	.50	.....	.....	June 24	July 10	16
		.50	.60	.20	.....	June 24	July 10	16
		.60	.25	.01	.02	June 25	July 10	15
		.95	.15	.25	.10	July 10	July 30	20
		.60	.40	.08	0	June 25	July 10	15
		.05	.05	0	0	June 26	July 9	13
	Apple	.10	0	.01	0	May 21	June 11	21
		.15	.....	.02	0	May 29	June 18	20
		.65	.75	.20	.04	June 6	June 18	12
		.50	.20	.08	0	June 16	July 1	15
		.70	.20	.02	0	June 25	July 10	15
	Cherry	.02	.02	.01	0	May 21	June 11	21
		.50	.....	.25	.....	June 16	July 1	15
	Peach	1.00	.90	.40	.60	June 25	July 10	15
		.75	.70	.30	.20	July 10	July 30	20
	Alder	.02	.01	0	0	July 10	July 30	20
	Poplar	.01	.01	0	0	July 10	July 30	20
Average Injuries		**.46—**	**.30+**	**.15+**	**.07—**			
Paris Green		0	.05	.02	0	May 21	June 11	21
		.25	.15	.02	.01	May 29	June 18	20
		.75	.60	.05	.....	June 24	July 10	16
	Plum	.50	.60	.25	.....	June 24	July 10	16
		.25	.10	.02	0	June 25	July 10	15
		.95	.55	.40	.....	June 6	June 18	12
		.60	95	.10	.15	July 10	July 30	10
		.50	.10	.02	.01	May 21	June 11	21
	Apple	.01	0	0	0	May 29	June 18	20
		.10	.....	.08	0	June 25	July 10	15
		.65	.50	.30	.05	June 6	June 18	12
	Cherry	0	0	0	0	May 21	June 11	21
		.35	35	.05	.05	June 25	July 10	15
	Peach	.75	.75	.12	.10	June 25	July 10	15
		.60	.10	.02	.04	July 10	July 30	20
	Alder	.02	0	0	0	July 10	July 30	20
	Poplar	.02	01	0	0	July 10	July 30	20
Average Injuries		**.37+**	**.30+**	**.09+**	**.03**			
White Arsenic		.05	0	0	0	May 21	June 11	21
		.04	.02	0	0	May 29	June 18	20
	Plum	.20	0	0	0	June 25	July 10	15
		.08	0	.01	0	June 6	June 18	12
		0	0	0	0	May 21	June 11	21
		0	0	0	0	May 29	June 18	20
	Apple	.20	.05	0	0	June 25	July 10	15
		.25	0	0	0	June 6	June 18	12
	Cherry	0	0	0	0	May 21	June 11	21
		.05	0	0	0	June 25	July 10	15
	Alder	0	0	0	0	June 25	July 10	15
Average Injuries		**.08—**	**.01—**	**0+**	**0**			

Comparative Injuries to Foliage from London Purple, Paris Green and White Arsenic, when Freshly Mixed and Applied in Water.

It will be seen from an examination of Table I, that either London purple or Paris green is many times more injurious to foliage than is white arsenic, when freshly mixed and applied in water; and that London purple, on the whole, does considerably more injury than Paris green. It will also be noticed that different trees vary greatly in their power to resist the action of these poisons. In my experiments, alder and poplar have not been seriously injured by applications as strong as one pound to twenty-five gallons. Cherry has been less injured than apple, and apple less than plum; while peach has been most susceptible of injury of any plant to which the poisons were applied, a pound to 200 gallons, in some cases destroying more than fifty per cent of the foliage.

Perhaps the most surprising thing set forth in the above table is that pure white arsenic applied to the foliage of plum, apple and cherry has in no case done serious harm, unless stronger than one pound to fifty gallons, and the average injury to plum foliage, when applied in the proportion of one pound to twenty-five gallons, is less than ten per cent. Last season I applied white arsenic in water to the foliage of apple, pear, peach, plum, cherry, alder, willow, poplar, soft maple, barbary and raspberry. A total of eighteen applications in the proportion of one pound to fifty gallons produced, in one case only, slight injury and that was upon peach foliage treated September 28 and noted October 18. The damage was estimated at .02. Forty-eight other applications in strengths varying from one pound to 100 gallons, to one pound to 800 gallons did no harm in any case.

In Table I it will be seen that in the proportion of one pound to twenty-five gallons the average injury from London purple has been .46; from Paris green, .37, and from arsenic .08. In the proportion of one pound to fifty gallons, London purple has averaged .30; Paris green .30, and arsenic .01 injury. In the proportion of one pound to 100 gallons, London purple has averaged .15; Paris green .09, and white arsenic no injury. In the proportion of one pound to 200 gallons, London purple has averaged .07; Paris green .03, and white arsenic no injury.

These results in case of white arsenic do not agree with those obtained by Professor Cook and presented in a paper before the Entomological Section of the A. A. A. S. last year

and which was also published in Bulletin 53 of the Michigan Experiment Station. It does not appear in that paper that more than one application was made with arsenic and that was upon peach. Professor Cook used arsenic in the proportion of one pound to 300 gallons of water and reported "great injury." I have made five applications of this poison upon peach foliage in the proportion of one pound to 300 gallons and in no case found any injury resulting. What can be the reason for this difference in results I am unable to say. I can only report faithfully the results obtained from my applications. In my experiments the arsenic was in every case freshly mixed and applied in pure well water, conditions that are important as will be seen farther on.

Increased Injuries to Foliage from Allowing the Arsenites to Remain in Water for a Time before Being Applied.

After determining in 1888 (See Bulletin 2 of the Iowa Experiment Station) that dissolved arsenic, even when extremely dilute, would do serious injury to foliage it occurred to me that in many instances where the arsenical mixtures had done unusual harm to foliage the reason might be found in the fact that they had been allowed to stand in water before being applied until they had become partially dissolved and, hence, the injury. Among the first of my experiments of last year were some to determine this point. In table II I have tabulated the injuries resulting from applications made this summer. None of the applications contained any of the poison in the solid state. The poison in each case was mixed in water in the proportion of the greatest strength used and allowed to stand for a time (indicated in days in the column at the left of the table) before being applied. On the day of application the water was carefully poured off leaving the residue in the bottom of the vessel. The weaker solutions were made by diluting the stronger. It will be noticed that in the case of London purple the injuries were about the same as those given in Table I where this poison was mixed and applied in the ordinary manner in water.

The water from Paris green, which is hardly at all soluble, did but slight harm in any case. Arsenic water did very serious harm. As dilute as 1 pound to 200 gallons it destroyed 90 per cent. of plum foliage and 25 per cent. of cherry foliage.

TABLE II.

Injuries to Foliage from Applications of Water in which London Purple, Paris Green and White Arsenic have for a time been Standing.

		Days in water.	1 Pound to 25 Gallons.	1 Pound to 50 Gallons.	1 Pound to 100 Gallons.	1 Pound to 200 Gallons.	Date applied.	Date noted.
London Purple	Plum	18	.60	.15	.10	.....	June 17	June 27
		23	....	.15	.15	0	June 26	July 11
	Apple	18	...	.20	.07	0	June 17	June 27
	Cherry	23	....	.50	.20	.05	June 26	July 11
	Alder	23	...	.05	.01	0	June 26	July 11
	Raspberry	23	....	.25	.15	.07	June 26	July 11
Paris Green	Plum	18	.07	.02	.01	0	June 17	June 27
		23	....	0	0	0	June 26	uly 11
	Apple	18	.01	.02	0	0	June 17	une 27
	Cherry	23	....	.02	0	0	June 26	uly 11
	Alder	23	....	0	0	0	June 26	July 11
	Raspberry	23	....	02	0	0	June 26	July 11
White Arsenic	Plum	18	1.00	.85	.40	.....	June 17	June 27
		23	....	.80	.50	.90	June 26	July 11
	Apple	18	...	.35	15	.	June 17	June 27
	Cherry	23	.50	.90	95	.25	June 26	July 11
	Alder	23	....	.15	10	.04	June 26	July 11
	Raspberry	23	....	.75	40	.30	June 26	July 11
Average Injuries	Lond'n purple	..	.60	22—	.11+	.02+		
	Paris green	..	.04	.01+	0+	0		
	W. Arsenic	..	.75	.63+	42—	37+		

*From the above table we shall conclude that when these poisons, especially London purple and white arsenic, are to be applied in water to foliage they should be used as soon as possible after being wet.

Effects of Adding Paste to Arsenites Mixed in Water.

When treating plum trees for the destruction of the Plum Curculio in the spring of 1889, I used one half ounce of flour made in paste to each gallon of the mixture of London purple in water. So much injury was done to the foliage that it was thought best to determine whether or not the paste was in any measure accountable for it. A number of applications were made for the purpose of determining this point and the injuries from such as are convenient for tabulation are given in Table III. The increased damage due to the addition of paste as set forth in the table is surprising indeed until thoughtfully consid-

*It may be that this is true of arsenic onl

ered. The injuries put down in the table are remarkable, however, not so much for being severe where paste was added as for being very light where paste was not used. By glancing at the right hand column it will be noticed that there were frequent rain falls while these applications were on. The first applications (made May 21) were followed by a dashing shower in less than twenty four hours and other heavy rains soon followed. As might be expected, very slight injury resulted from any application made at that time where paste was not added, except in one instance upon apple in the proportion of one pound to twenty five gallons. In this case the twigs may have been protected by an overhanging branch. It is one of the exceptions that can not be accounted for. The applications made June 6 were followed by light showers that kept the leaves wet much of the time without giving them a thorough washing and the injuries resulting from that day's applications average very high in consequence.

TABLE III.

Table Showing Comparative Injuries to Foliage from the Arsenites when Applied in Water, with and without the addition of Flour Paste.

		1 LB. TO 25 GAL.		1 LB. TO 50 GAL.		1 LB. TO 100 GAL.		1 LB. TO 200 GAL.					
		Without Paste.	With Paste.	Without Paste.	With Paste.	Without Paste.	With Paste.	Without Paste.	With Paste.	Date applied.	Date noted.	Number days.	* Rained.
London Purple.	Plum.	.85	95	.75	.80	.80	.33	.08	.0	June 6	June 18	12	May 22[2]
		.05	.30	0	.25	.02	.10	0	.05	May 21	June 11	21	May 30[3]
		.....	.....	.....	.....	.50	.90	.35	.80	.....	.....	.....	June 2[3]
	Apple.	.65	.95	.25	.25	.20	.20	.04	.10	June 6	June 18	12	June 3[3]
		.10	.25	0	.50	.01	.10	0	.02	May 21	June 11	21	June 4[1]
	Cherry.	.02	.10	.02	.08	.01	.01	0	.....	May 21	June 11	21	June 9[1]
													June 13[1]
Average Inj.		.33+	.51—	.20+	.38—	.25+	.27+	.08—	.23+				June 14[1]
													June 18[1]
Paris Green.	Plum.	.95	1.00	.55	.90	.40	.30	.08	.25	June 6	June 18	12	
		0	.25	.05	20	.02	.25	0	.08	May 21	June 11	21	
		.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
	Apple.	.65	.90	.50	.50	.30	.04	.05	01	June 6	June 18	12	
		.50	.90	.10	.80	.02	.50	.01	.02	May 21	June 11	21	
	Cherry.	0	0	0	.02	0	.01	0	.01	May 21	June 11	21	
Average Inj.		.42	.63	.24	.48+	.15—	.23	.03—	.06+				

*The figures (1), (2) and (3) indicate light, rather heavy, and heavy rains, respectively.

It is also shown in Table III that London purple or Paris green in the proportion of one pound to 200 gallons of water with paste upon foliage as tender as that of plum is not safe, as high as twenty and even eighty per cent. injuries having resulted from applications in this strength. I suppose that the increased injury from the use of the paste is due entirely to its adhesive property causing the poisons to remain for a longer time and in larger quantities upon the foliage.

Judging from my experiments, I should say that when the arsenites are used with paste they must be applied much more dilute than is ordinarily recommended or they will be liable to do considerable injury to foliage. I have also noticed in the course of my experiments that the burning of the foliage continues for a much longer time when paste is added to the mixtures, as long as a month or even two months being required in some cases to complete the injuries.

Soap Added to Arsenical Mixtures.

London purple, Paris green and white arsenic were also applied to foliage in water that had been made slightly soapy and considerable evidence of increased injury as the result was obtained. The applications were not repeated and final conclusions can not be drawn. I give farther on the effects of mixing the arsenites with strong soapy mixtures such as are used for the destruction of insects by external contact.

Best Time to Apply Arsenical Mixtures.

Time of Day.—I have been unable to find any satisfactory evidence that one hour of the day is better than another for the application of the arsenicals in water. A sufficient number of applications have not been made for comparison in this manner to enable one to arrive at positive conclusions. Nearly all of the applications reported in this paper have been made in the middle of the day, some of the days very bright and warm and others cool and cloudy but no difference in injury from these causes have been noticeable to me.

Applying Before or After Rain.—Many of my applications have been followed in a few hours by a fall of rain and I have on two occasions gone out upon a misty lowery day when the rain was falling very gently and made quite a large number of applications in varying strengths on different kinds of foliage but I have been able to detect but one effect from a

rain and that is to lessen the injury. Certainly a heavy rain or a dashing shower following soon after an application lessens the injury very materially. I have not suitable notes to form a table showing comparative injuries in this case but an account of applications to a large number of plum trees and the injuries resulting therefrom will serve the same purpose.

Fifteen plum trees were thoroughly treated with London purple in water in the following proportions and on the following dates the past spring:

May 1, one pound to 200 gallons; May 10, one pound to 250 gallons; May 14, one pound to 300 gallons; May 26, one pound to 250 gallons; June 2, one pound to 256 gallons; June 7, one pound to 256 gallons. In all, six applications, the weakest of which is as strong as is thoroughly safe to apply to plum foliage, yet, in most cases, but little harm resulted. As near as I can estimate the trees lost from ten to twenty-five per cent of their leaves. In an ordinary season they would probably have lost nearly their entire foliage. In the above case, however, every application but the last was soon followed by a heavy rain or a dashing shower. Up to the time of making the last application only the slightest injury was apparent.

I can readily see how a very light fall of rain, not causing the leaves to drip much, might increase the injury by giving the poison a better opportunity to become dissolved, especially, if a little paste were added to retain the poison upon the leaves.

Lime Added to the Arsenites to Prevent Injury to Foliage.

Perhaps the most interesting and valuable results reached in the experiments here reported came from adding milk of lime to arsenical mixtures to lessen the damage to foliage. So far as the writer is aware no work has previously been done with this object in view. My first experiments in this line were made in the fall of 1889 and very encouraging results were reached but the lateness of the season prevented their repetition until the present year. London purple and Paris green occasionally do so much damage to foliage, even when used quite dilute, that entomologists have almost ceased to recommend their use on very tender foliage like that of the peach. But I find that by adding a little lime to London purple or Paris green in water that they can be safely

used in moderate strengths upon the tenderest foliage. By referring to Table IV it will be seen that by the addition of lime these poisons, especially the London purple, can be used three or four times as strong as when the lime is omitted. In the course of my experiments the greatest injury done by London purple in the proportion of one pound to 200 gallons of water with the addition of lime was .01 in one case upon peach. In the proportion of one pound to 100 gallons the greatest injuries were .05 in one case upon peach and .04 in one case upon plum. Upon apple one pound to fifty gallons did not in any case exceed .02 injury and one pound to twenty five gallons did not do serious harm.

The general average of injuries for this poison with lime as obtained from Table IV are:

In the proportion of one pound to twenty five gallons, .14; in the proportion of one pound to fifty gallons, .04; in the proportion of one pound to 100 gallons, .01; in the proportion of one pound to 200 gallons, none. The applications were made, as shown in the table, upon the foliage of plum, apple, cherry, peach, alder, locust, poplar, grape and squash.

Without the addition of lime the injuries were, respectively, 56, 31, 17 and 9 per cent.

It seems to the writer that the discovery of this use of lime is a matter of much importance as it makes it safe to use London purple, and perhaps Paris green as well, upon tender foliage like that of the peach and plum and will also make it safe to apply much heavier doses of these poisons for the more effectual destruction of such insects as the Plum Curculio, Plum Gouger, Flea Beetles, Blister Beetles and the like.

What seems strange in regard to this use of lime is that when it is used with white arsenic it should produce the exact opposite effect that it produces in case of London purple or Paris green. It will be seen by referring to Table IV that the white arsenic did from three to twenty times as much damage when combined with lime as when the lime was left out. Lime added to arsenic in solution, however, as can be seen from Table V, materially lessens the damage that it would otherwise do to foliage. I think it possible that the increased injury may be due principally to the mechanical effect of the lime in retaining more of the arsenic upon the leaves for I believe that this poison is much more easily removed by wind and rain than is either London purple or Paris green.

TABLE IV.

Table Showing Effects upon Foliage from the Addition of Lime to Arsenical Mixtures in Water.

		1 LB. TO 25 GAL.		1 LB. TO 50 GAL.		1 LB. TO 100 GAL.		1 LB. TO 200 GAL.		Date applied.	Date noted.
		Without Lime.	With Lime.	Without Lime.	With Lime.	Without Lime.	With Lime.	Without Lime.	With Lime.		
London Purple.	Plum	.85	.20	.75	.05	80	0	.08	0	June 6	June 21
		.80	.08	.70	30	.30	.04	....	....	June 16	July 1
		.60	.20	.25	0	.01	0	.02	0	June 25	July 10
	Apple	.95	.25	.15	.10	.25	.10	.10	0	July 10	July 30
		.65	.04	.25	0	.20	0	.04	0	June 6	June 21
		.50	.05	.20	.01	.08	0	....	....	June 16	July 1
		.60	.05	.40	.02	.08	0	0	0	June 25	July 10
		.05	0	.05	0	0	0	0	0	June 26	July 9
	Cherry	.50	02	....	.01	.25	0	....	....	June 16	July 1
	Peach	.70	.01	.20	0	.01	0	0	0	June 25	July 10
		.75	.55	.70	.02	.30	.04	.20	.01	July 10	July 30
		.99	.60	.90	.02	.40	.05	.60	0	June 25	July 10
	Alder	.02	0	.01	0	0	0	0	0	July 10	July 30
	Poplar	.01	0	.01	0	0	0	0	0	July 10	July 30
	Grape	.50	05	.15	....	.08	0	....	....	June 16	July 1
	Squash	....	10	0	0	0	0	0	0	June 26	July 9
	Average Inj	.56+	.14—	.31+	.04—	.17+	.01+	.09—	0+		
Paris Green	Plum	.95	.20	.55	.08	.40	10	....	.10	June 6	June 21
		.25	.10	.10	0	.02	0	0	0	June 25	July 10
		.60	.75	.95	.25	.10	.10	.15	.04	July 10	July 30
	Apple	.65	.04	.50	.02	.30	01	.05	0	June 6	June 21
		.10	.04	....	.02	.08	0	.01	0	June 25	July 10
	Peach	.75	.20	.75	.15	.12	.05	.10	.15	June 25	July 10
		.60	.25	10	.05	.02	.02	.04	.02	July 10	July 30
	Cherry	.35	.01	.35	0	.05	0	.05	0	June 25	July 10
	Alder	.2	0	0	0	0	0	0	0	July 10	July 30
	Poplar	.02	.01	01	.01	0	0	0	0	July 10	July 30
	Average Inj	.43—	.16	.35—	05+	.11—	.03—	.04+	.03—		
White Arsenic. (Not dissolved.)	Plum	.15	1.00	.02	.70	.02	.50	.01	.08	June 6	July 21
		.20	.60	0	.50	0	.20	0	.05	June 26	July 10
	Apple	0	.25	0	.10	0	.01	0	0	June 6	July 21
		.20	.95	.05	.50	0	.10	0	.04	June 26	July 10
	Alder	0	.10	0	.0	0	.05	0	0	June 26	July 10
	Average Inj	.11	58	.01+	.36	0+	.17+	0+	.03+		

In these experiments the lime was prepared by putting about a bushel of the lumps in a barrel and covering well with water until all had slaked. Each time before removing the lime water for use, it was stirred until very milky and then the quantity wanted was dipped out and more water was added to be ready for use at another time. It was my intention each time to have as much lime in the water as could be used without clogging the sprayer.

The left hand column of each double column in these two tables show the percentage of injury in each case where the poison was freshly mixed in pure water and applied and the companion column shows the effects where lime was added. The surprising differences shown in favor of adding lime are very gratifying indeed.

TABLE V.

Showing Injuries to Foliage from Arsenical Solutions with and without the Addition of Lime.

		1 Lb. to 50 Gal.		1 Lb. to 100 Gal.		1 Lb. to 200 Gal.		1 Lb. to 400 Gal.		1 Lb. to 800 Gal.		1 Lb. to 1600 Gal.		Applied.	Noted.
		No Lime.	Lime.	No Lime.	Lime.	No Lime.	Lime.	No Lime.	Lime.	No Lime.	Lime.	No Lime.	Lime.		
[1]L. P. Water.	Plum	.15	0	.15	0	0	0	...	.....	.....	.....	.....	.....	June 26	July 11
	Cherry	.50	0	.20	0	.05	0	...	.....	.....	.....	.....	.....	June 26	July 11
	Alder	.05	0	.01	0	0	0	...	.....	.....	.....	.....	.....	June 26	July 11
	Raspberry	.25	0	.15	0	.07	0	...	.....	.....	.....	.....	.....	June 26	July 11
	Av. Injury	.24—	0	.13—	0	.03	0	...	.....	.....	.....	.....	.....		
[2]Arsenic Water.	Plum	.80	.35	.50	.10	.90	0	...	.....	.....	.....	.....	.....	June 26	July 11
	Cherry	.90	...	.95	.10	.25	0	...	.....	.....	.....	.....	.....	June 26	July 11
	Alder	.15	.05	.10	0	.04	0	...	.....	.....	.....	.....	.....	June 26	July 11
	Av. Injury	.62—	.20	.52—	.07—	.40—	0	...	.....	.....	.....	.....	.....		
[3]Arsenic Solution.	Plum	.....	.....	.90	.10	.60	0	.85	0	.60	0	.20	0	July 10	July 24
		.....	.....	.....	.....	1.00	.30	.98	07	50	0	.05	0	July 3	July 24
	Thorn	.....	.....	.....	.....	.20	0	12	0	.08	0	.04	0	July 3	July 24
	Alder	.....	.....	.....	.....	.10	0	.05	0	.05	0	.01	0	July 3	July 24
	Apple	.....	.....	.20	.02	.05	0	.05	0	0	0	0	0	July 10	July 24
	Av. Injury	.....	.....	.55	.06	.39	.06	.41	.01+	.25—	0	.06	0		

[1] Water in which London purple has stood 23 days.
[2] Water in which white arsenic has stood 23 days.
[3] Water in which white arsenic has been entirely dissolved by boiling.

Arsenites Mixed with Insecticides that Kill by External Contact.

Entomologists in this country have begun to recommend the combination of the arsenites with insecticides that kill by external contact so that with one application the mandibulate or biting insects and the haustellate or sucking insects may be destroyed. Whether or not the arsenites can be readily mixed with these compounds, and, when mixed, whether or not they can be safely applied to foliage, are questions that should be settled before such combinations are recommended. So far as the writer is aware but very little has yet been done in this direction.

In Insect Life, vol. II, page 276, is printed a letter from a Mr. J. W. Van Deman of Benzonia, Michigan, in which Mr. Van Deman states that he sprayed an orchard with London purple and kerosene emulsion combined for the destruction of the Codling Moth and Bark-lice at one application. Before reading that letter I had persistently tried every method that I could think of to mix London purple, Paris green and white arsenic with kerosene emulsion and had fully decided in my own mind that, by any method I had tried, it was entirely impracticable. In my attempts to combine the arsenicals with kerosene emulsion, whether first mixed in water, in soap, in kerosene, or in other ways, they would always separate out when properly diluted for application in buttery clots that would quickly go to the top or bottom or sides of the vessel and these clots would adhere to everything that they touched with a greasiness that almost defied all attempts at removal. I therefore wrote Mr. Van Deman asking him how he proceeded to mix London purple and kerosene emulsion in the case above referred to and if he was *sure* that he really did get a satisfactory mixture. From his reply it was learned that his experiment has no argument in it in favor of mixing these substances. The emulsion was prepared in the barrel ready for application and the London purple was added under the supposition that it would mix properly but that it did there was no evidence. It is not known even that the application was of any use in destroying the insects to which it was applied.

From Mr. Van Deman's letter in reply to my inquiries I extract the following:

"*Dear Sir:*—The article in Insect Life was hastily written merely as a report that I had done the work, and I have no copy of the text at hand. I had sprayed sixty trees with the emulsion and then he wanted me to spray thirty trees with both the emulsion and the London purple, so, to save time, I mixed them. I think I wet the London purple with kerosene or with emulsion and then put it in the barrel and mixed by pumping, and sprayed it over the leaves with a Lewis pump. I remember that there was a considerable purple in the last bucket-full I took from the barrel that would not have gone through an atomizer. There was a frost after corn planting that destroyed young apples entirely so I could not tell the success of the purple as applied.

Yours truly, J. W. VAN DEMAN."

"Benzonia, Michigan, April 9, 1890."

London Purple and Paris Green in Rosin Mixtures.

No trouble was experienced in mixing London purple and Paris green in rosin compounds prepared according to the formula given by Mr. Coquillett on page 130 of the Report of the Commissioner of Agriculture for 1888. The poisons were first wet in a small quantity of water and then poured into the rosin compound. Not only was this mixture easily made but it was found, as shown in Table VI, that the injury to foliage from this combination was not worse than that done by these poisons when applied alone in the usual manner.

TABLE VI.

Showing Injuries to Foliage from applications of London Purple and Paris Green in Rosin Mixtures.

		1 Pound to 25 Gallons.	1 Pound to 50 Gallons.	1 Pound to 100 Gallons.	1 Pound to 200 Gallons.	Applied.	Noted.	Days standing.
London Purple	Plum	.75	.40	.10	.08	July 9	July 23	14
	Apple	.08	.01	.01	0	July 9	July 23	14
	Locust	.20	.10	.10	0	July 9	July 23	14
Average Injuries		**.34+**	**.17**	**.07**	**.03—**			
Paris Green	Plum	.10	.04	.02	0	July 9	July 23	14
	Apple	.04	.03	.02	0	July 9	July 23	14
	Locust	.05	.08	0	.02	July 9	July 23	14
Average Injuries		**.06+**	**.05**	**.01+**	**.01—**			

London Purple and Paris Green in Soapy Mixtures.

In Table VII, I have given percentages of injury to foliage when London purple or Paris green is added to a solution of soap sufficiently strong to destroy soft-bodied insects. In these experiments the soapy mixture was made by dissolving four ounces of whale-oil soap in one gallon of water. The injuries, as shown in the table, were much more severe than when these poisons were applied in water. With a weaker soap solution, however, the injury might not have been so severe, as the soap solution itself applied to plants did injury as follows: to plum, .05; to locust, .02; to squash, .01, and to apple none.

TABLE VII.

Showing Injuries to Foliage from applications of London Purple and Paris Green in a strong Soapy Mixture.

		1 Pound to 25 Gallons.	1 Pound to 50 Gallons.	1 Pound to 100 Gallons.	1 Pound to 200 Gallons.	Date applied	Date noted.	Days standing.
London Purple	Plum	1.00	.98	.85	.20	July 9	July 23	14
	Apple	.40	.25	.10	.02	July 9	July 23	14
	Locust	.90	.50	.20	.04	July 9	July 23	14
Average Injuries		.77—	.57+	.38+	.09—			
Paris Green	Plum	.50	.85	.65	.15	July 9	July 23	14
	Apple	.15	.08	.05	0	July 9	July 23	14
	Locust	.80	.75	.07	.01	July 9	July 23	14
Average Injuries		.48+	.56	.26—	.05+			

Combining Arsenites with Fungicides.

Bordeaux Mixture.—In Bulletin 7, Vol. II, of the Ohio Exp. Sta., Prof. Weed reports having used London purple in Bordeaux mixtures with very satisfactory results, but farther than this we are not informed. My own experiments here reported were made for two purposes: first, to determine the effect that such a mixture would have upon foliage; and, second, to determine whether or not it would be effectual in destroying leaf-feeding larvae. Of all the substances I have used in combination with the arsenites in the course of my experiments, none can be compared with Bordeaux mixture for the prevention of injury to foliage. Perhaps it can scarcely be believed, but it is none the less true, that I have been unable to produce the least harm upon plum or peach foliage with London purple in standard Bordeaux mixture, in the proportion of one pound to fifty gallons. In the proportion of one pound to twenty-five gallons the injury to peach has been very slight, while upon plum it has not done the least injury (see Table VIII). In using this mixture I sprayed, not a few leaves of peach and plum, but the foliage of several large branches. As a severe test I made one application of London purple in Bordeaux mixture to a large amount of plum and apple foliage, in the proportion of one pound to ten gallons. Two weeks afterward the plum foliage showed a damage of about ten per cent, and the apple foliage showed no injury at all. This almost perfect immunity from harm

is probably due in greater part to the presence of lime and copper hydrate to precipitate at once any arsenic that might pass in solution.

As this mixture will enable us to destroy fungi (microscopic plants causing rusts, blights and mildews) and many injurious insects with one application, it seems to the writer to be a matter of much importance.

TABLE VIII.

Table Showing almost Perfect Exemption from Injury to Foliage when London Purple is applied in Bordeaux Mixture.

		1 Pound to 25 Gallons.	1 Pound to 50 Gallons.	1 Pound to 100 Gallons.	1 Pound to 200 Gallons.	Date applied.	Date noted.
Lond'n Purple in *Bordeaux Mixture.....	Plum....	.....	0	0	0	June 13	July 2
		.01	0	0	0	July 2	July 24
		0	0	0	0	July 17	August 30
	Alder....	0	0	0	0	July 2	July 24
			0	0	0	July 17	August 30
	Apple.....	0	0	0	0	July 17	August 30
	Peach.	.02	0	0	0	July 17	August 30
	Cherry....	0	0	0	0	July 17	August 30
	Grape.....	0	0	0	0	July 17	August 30

*The lime in the mixture was not measured. As much was used as would go through the nozzle without clogging.

London Purple in Sulphate of Copper Solution.

The severe injuries resulting from applications of London purple in a simple sulphate of copper solution make it certain that this combination should never be used upon foliage. It will be sufficient to state that London purple mixed in a sulphate of copper solution, of the strength used for fungicidal purposes, in the proportion of one pound of the poison to 200 gallons of the solution, destroyed every leaf upon portions of cherry trees to which it was applied. London purple as ordinarily applied in water in this strength should not do the slightest injury to cherry foliage.

TABLE IX.

Showing Injuries to Foliage from applications of London Purple in Solutions of Sulphate of Copper (Blue-Stone).

	1 Pound to 25 Gallons.	1 Pound to 50 Gallons.	1 Pound to 100 Gallons.	1 Pound to 200 Gallons.	Applied.	Noted.	Days standing.
Plum	1.00	.65	.50	.....	July 25	Aug. 9	15
	.....	1.00	1.00	1.00	Aug. 1	Sept. 9	22
Apple	.40	0	.....	.....	July 25	Aug. 9	15
Cherry	.98	.50	.....	.....	July 25	Aug. 9	15
	.....	1.00	1.00	1.00	Aug. 18	Sept. 9	22
Alder	.01	0	0	0	July 25	Aug. 9	15
Mulberry	.....	.70	.10	.05	Aug. 18	Sept. 9	22
Average Injury	**.60—**	**.55**	**.52**	**.51+**			

Arsenites in Carbonate of Copper Solution.

As carbonate of copper is coming into prominence as a fungicide, an ammoniacal solution of this substance was used in which to mix the arsenites for application to foliage. The results reached were not uniform but in the majority of cases the injury resulting was less than when water only was used. If this mixture is to be used, however, I would recommend that the poison be used rather dilute until it is found by experiment that it can be applied stronger.

TABLE X.

Showing Injuries to Foliage from applications of London Purple in an Ammoniacal Solution of Carbonate of Copper.

	1 Pound to 25 Gallons.	1 Pound to 50 Gallons.	1 Pound to 100 Gallons.	1 Pound to 200 Gallons.	Applied.	Noted.	Days standing.
*Plum	.99	.90	.60	.50	July 25	Aug. 9	15
	.....	.90	.20	.35	Aug. 18	Sept. 9	22
Apple	.02	.01	0	0	July 25	Aug. 9	15
Cherry	.....	.15	.20	0	Aug. 18	Sept. 9	22
Alder	.02	.01	0	0	July 25	Aug. 9	15
Average Injury	**.34+**	**.39+**	**.20**	**.17**			

*The Carbonate of Copper solution alone injured plum foliage, which probably accounts for the serious injuries shown in the table.

Feeding Experiments.

My only feeding experiments have been with the larvae of *Datana ministra* (?) feeding upon black-walnut. Large numbers of the larvae were brought into the laboratory and fed on leaves that had been treated with London purple, Paris green and white arsenic respectively, in the proportion of one pound to 200 gallons in lime water and in Bordeaux mixture. In every case the larvae were all destroyed in from twelve to forty-eight hours. Trees were also sprayed with London purple and with dissolved white arsenic in lime water, and the next day the ground beneath the trees were strewn with dead larvae.

*Conclusions.

*1. *The oldest leaves are most susceptible to injury from arsenical applications. They often turn yellow and drop without showing the burnt spotted appearance.*

*2. *Dews, and probably direct sunlight, increase the injuries done by the arsenites to foliage.*

*3. *Leaves kept perfectly dry can hardly be injured by the arsenites, even when they are applied very abundantly.*

4. Applications made in the heat of the day and in the bright sunlight do not injure foliage more than when applied in the cool of the day.

*5. *The only effect of a heavy rain or dashing shower following an application of one of the arsenites is to lessen the injury to foliage.*

6. Leaves suffering from a fungous disease are more susceptible to injury than are healthy leaves.

*7. *When freshly mixed and applied, London purple is most and white arsenic is least injurious to foliage.*

*8. *White arsenic in solution should not be used upon foliage without first adding lime, Bordeaux mixture or some other substance to prevent its injurious effects upon foliage.*

*9. *White arsenic, if allowed to stand many days in water before being applied, will do far greater harm to foliage than if applied as soon as mixed.*

*10. *Lime added to London purple or Paris green in water greatly lessens the injury that these poisons would otherwise do to foliage.*

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*I have put in italics those conclusions that seem to me to be well proven from the experiments here reported. Concerning the others there is some doubt, and further experiments are necessary to determine positively the facts.

11. Lime added to a mixture of white arsenic in water will greatly increase the injury that this poison would otherwise do to foliage. If the arsenic is all in solution, the lime will then lessen the injury, as in the case of London purple or Paris green.

12. London purple (Paris green and white arsenic have not yet been tried) can be used, at least, eight or ten times as strong without injury to foliage if applied in common Bordeaux mixture instead of water.

13. The arsenites cannot by any ordinary method be successfully mixed in a kerosene emulsion.

14. The arsenites mix readily in rosin compounds and do not seem to be more injurious to foliage than as ordinarily applied in water.

15. The arsenites in strong soapy mixtures do considerable more harm to foliage than when applied in water only.

16. The arsenites mix readily in carbonate of copper solution and do not seem to do more harm than when applied in water only.

17. London purple in sulphate of copper solution does vastly more harm than when applied in water only.